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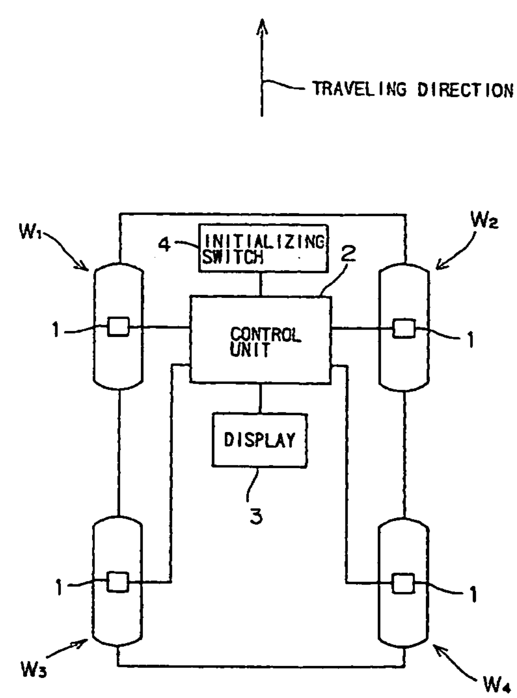
(54) Device for calculating initial correction factor for correcting rotational angular velocity of tire

(57) A device for calculating a correction factor for correcting an output of a rotational angular velocity detecting device for detecting the rotational angular velocities of right and left tires mounted on a vehicle. Discrimination between a state where the vehicle is linearly traveling and a state where the vehicle is traveling on a curved path is made on the basis of the output of the rotational angular velocity detecting device. Only when it is judged that the vehicle is linearly traveling, an initial correction factor for eliminating the effect of a difference in effective rolling radius between the tires depending on an initial difference on the rotational angular velocities of the tires is calculated.

FIG. 1



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Description

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to an initial correction factor calculating device used for a tire pressure drop detecting device, for example, for finding an initial correction factor for eliminating the effect of a difference in effective rolling radius depending on an initial difference between tires on the rotational angular velocities of the tires.

Description of Related Art

In recent years, as an example of a safety device of a four-wheel vehicle such as an automobile or a truck, devices for detecting the drop in air pressure of a tire (DWS) have been developed, and some of them have been put to practical use.

An example of a method of detecting the drop in air pressure of a tire is a method utilizing a difference among the respective rotational angular velocities F_1, F_2, F_3, and F_4 of four tires W_1, W_2, W_3, and W_4 mounted on a vehicle. This method utilizes the fact that the rotational angular velocity F_i (i = 1, 2, 3, 4) changes depending on the conditions of the air pressure of the tire W_i. That is, when the air pressure of any one of the tires W_i drops, the effective rolling radius of the tire W_i decreases. As a result, the rotational angular velocity F_i of the tire W_i increases. Therefore, the drop in the air pressure of the tire W_i can be judged on the basis of a difference in the rotational angular velocity F_i.

The effective rolling radius is a value obtained by driving the travel distance of the tire W_i freely rolling in a loaded state by one rotation by 2π.

A judgment expression used in detecting the drop in the air pressure of the tire W_i on the basis of the difference in the rotational angular velocity F_i is the following equation (1), for example (see Japanese Patent Laid-Open No. 305011/1988, Japanese Patent Laid-Open No. 212609/1992, etc.):

$$D = \frac{\frac{F_1 + F_4}{2} - \frac{F_2 + F_3}{2}}{\frac{F_1 + F_2 + F_3 + F_4}{4}} \times 100 \qquad (1).$$

If all the effective rolling radii of the tires W_i are the same, the respective rotational angular velocities F_i are the same ($F_1 = F_2 = F_3 = F_4$). Consequently, a judged value D is zero. Therefore, thresholds D_{TH1} and D_{TH2} (where D_{TH1}, $D_{TH2} > 0$) are set. When the condition given by the following expression (2) is satisfied, it is judged that there is a tire W_i whose air pressure drops. When the condition is not satisfied, it is judged that all the tires W_i have normal internal pressure.

$$D < -D_{TH1} \text{ or } D > D_{TH2} \qquad (2).$$

The effective rolling radius of the actual tire W_i includes a variation within a production tolerance (hereinafter referred to as an "initial difference"). That is, even if all the four tires W_i have normal internal pressure, the effective rolling radii of the four tires W_i differ depending on the initial difference. Correspondingly, the rotational angular velocities F_i of the tires W_i vary. As a result, the judged value D may be a value other than zero. Therefore, it may be erroneously judged that the air pressure drops, although it does not drop. In order to detect the drop in the air pressure with high precision, therefore, it is necessary to eliminate the effect of the initial difference from the detected rotational angular velocity F_i.

As a technique for eliminating the effect of the initial difference from the rotational angular velocity F_i, it is considered that a technique disclosed in Japanese Patent Laid-open No.318584/1995 is applied. In the technique, the ratio of the rotational angular velocities of right and left following tires is calculated. Further, a time-differentiated value of the ratio of the rotational angular velocities is calculated. It is judged whether or not the time-differentiated value remains at not more than a predetermined limit value over a predetermined time period. If the time-differentiated value remains at not more than the limit value over a predetermined time period, it is judged that the vehicle is linearly traveling. An initial correction factor is calculated on the basis of the rotational angular velocities F_i calculated at this time.

The initial correction factor is calculated only when it is judged that the vehicle is linearly traveling. Therefore, the calculation is not affected by the difference between the rotational angular velocities F_i of inner and outer tires which occurs at the time of cornering. Therefore, an initial correction factor faithfully representing a variation in effective rolling radius depending on an initial difference between tires W_i should be calculable.

In the above-mentioned prior art, however, a time-differentiated value of the ratio of the rotational angular velocities of right and left following tires is used as a basis for judgment whether a vehicle is linearly traveling. Therefore, it may, in some cases, be erroneously judged that the vehicle is linearly traveling, although it is cornering.

Specifically, when the vehicle is traveling on a road having an almost constant radius of curvature (hereinafter referred to as a "constant-R road"), for example, an exit road leading to a tollgate from an exit of a main lane in an interchange of a highway, it is erroneously judged that the vehicle is linearly traveling. More specifically, when the vehicle is traveling on such a constant-R road, a time-differentiated value of the ratio of the angular velocities is relatively small, and is hardly changed. In this case, it is judged that the time-differentiated value of

the ratio of the angular velocities remains at not more than the limit value, and it is erroneously judged that the vehicle is linearly traveling.

In this case, therefore, an initial correction factor which is affected by a variation in the rotational angular velocity F_i caused by cornering is calculated, whereby the rotational angular velocity F_i is erroneously corrected. As a result, the drop in air pressure of a tire is erroneously judged.

SUMMARY OF THE INVENTION

An object of the present invention is to provide an initial correction factor calculating device capable of reliably discriminating a state where a vehicle is linearly traveling from the other state and consequently, obtaining an initial correction factor faithfully representing a difference in effective rolling radius depending on an initial difference between tires.

Another object of the present invention is to provide a method of calculating an accurate initial correction factor by reliably discriminating a state where a vehicle is linearly traveling from the other state.

A device according to the present invention is a device for calculating a correction factor for correcting an output of rotational angular velocity detection means for detecting the rotational angular velocities of right and left tires mounted on a vehicle, which comprises traveling state judging means for judging whether the vehicle is linearly traveling or the vehicle is traveling on a curved path on the basis of the output of the rotational angular velocity detection means, and factor calculation means for finding an initial correction factor for eliminating the effect of a difference in effective rolling radius between the tires depending on an initial difference on the rotational angular velocities of the tires on the basis of the output of the rotational angular velocity detection means when the traveling state judging means has judged that the vehicle is linearly traveling. The curved path includes a path having an almost constant radius of curvature.

According to the present invention, the discrimination between the state where the vehicle is linearly traveling and the state where it is traveling on a path having an almost constant radius of curvature is made. When the vehicle is traveling on a path having an almost constant radius of curvature, therefore, it is not erroneously judged that the vehicle is linearly traveling. Consequently, it is possible to obtain an initial correction factor faithfully representing the difference in effective rolling radius depending on the initial difference between the tires. If the present invention is applied to a tire pressure drop detecting device, therefore, it can be reliably judged whether or not the air pressure of the tire has dropped.

Even if it is not examined whether or not a state where it is judged that the vehicle is linearly traveling is continuing for a predetermined time period, the discrimination between the state where the vehicle is linearly traveling and the state where it is traveling on a path having an almost constant radius of curvature can be reliably made because the above-mentioned traveling state judging processing is performed. Even in a short straight road, it can be reliably recognized that the vehicle is linearly traveling.

The traveling state judging means may include means for calculating the ratio of the rotational angular velocities of the right and left tires on the basis of the output of the rotational angular velocity detection means, and means for judging whether or not the difference or the ratio between the calculated ratio of the rotational angular velocities of the right and left tires and reference data corresponding to the ratio of the rotational angular velocities of the right and left tires previously calculated is less than a predetermined threshold, and judging that the vehicle is linearly traveling when it is judged that the difference or the ratio is not more than the threshold, for example.

When the vehicle is traveling on a road having an almost constant radius of curvature, the ratio between the rotational angular velocities of the right and left tires generally falls in a predetermined range. If the above-mentioned threshold is set to a value which is less than the minimum value of a range in which the difference or the ratio falls, therefore, the discrimination between the state where the vehicle is linearly traveling and the state where it is traveling on a road having an almost constant radius of curvature can be reliably made.

The factor calculation means may be one for subjecting the ratio of the rotational angular velocities of the right and left tires which is obtained on the basis of the output of the rotational angular velocity detection means and the initial correction factor previously found to averaging processing, to find an initial correction factor. In this case, the initial correction factor found by the factor calculation means may be used as reference data to be used in the traveling state judging means.

In the present invention, the initial correction factor is found by performing averaging processing, whereby the precision of the initial correction factor is improved as the initial correction factor is calculated. Consequently, the precision of the judging processing in the traveling state judging means utilizing such an initial correction factor as reference data is improved as the initial correction factor is repeatedly calculated. Therefore, it can be more reliably recognized that the vehicle is linearly traveling.

The device according to one embodiment of the present invention further comprises means for calculating a time-differentiated value of a value corresponding to the turning radius of the vehicle (for example, the reciprocal of the turning radius) on the basis of the output of the rotational angular velocity detection means, and means for allowing judging processing in the traveling state judging means to be performed on condition that the calculated time-differentiated value falls in a

predetermined allowable range.

When the vehicle is linearly traveling, the reciprocal of the turning radius of the vehicle is stable at an offset value corresponding to a variation due to the initial difference between the right and left tires, for example.

Consequently, the time-differentiated value is approximately zero. When the time-differentiated value falls in the allowable range, therefore, it can be presumed that the vehicle is linearly traveling. The traveling state judging processing can be performed, excluding a state where a case where the possibility that the vehicle is linearly traveling is significantly low, for example, a case where the vehicle is going to curve a right angle corner. Specifically, the discrimination processing is performed only when it is presumed that the vehicle is linearly traveling, whereby the efficiency of the processing can be increased.

The device according to one embodiment of the present invention further comprises means for subjecting the ratio of the rotational angular velocities of the right and left tires which is obtained on the basis of the output of the rotational angular velocity detection means and initial data previously found to averaging processing, to find initial data, means for recording the number of times of calculation of the initial data, means for judging whether or not the recorded number of times of calculation reaches a predetermined threshold, means for inhibiting the judging processing in the traveling state judging means from being performed until it is judged that the number of times of calculation reaches the threshold, and means for setting the initial data as reference data to be first used in the traveling state judging means. In this case, the device may further comprise means for performing processing for finding the initial data on condition that the calculated time-differentiated value falls in the allowable range.

In this construction, the judging processing in the traveling state judging means is inhibited until the number of times of calculation of the initial data corresponding to the ratio of the rotational angular velocities of the right and left tires reaches the threshold. In other words, the traveling state judging processing in the traveling state judging means is not performed until the number of times of calculation of the initial data reaches the threshold. In this case, initial data after calculation whose number of times corresponds to the threshold is used as the reference data to be used for the first traveling state judging processing.

The initial data is found by the averaging processing when it can be presumed that the vehicle is linearly traveling. When the number of times of calculation reaches the threshold, the initial data has sufficient precision. Consequently, the judging processing can be performed with high precision from the beginning. Accordingly, it can be more reliably recognized that the vehicle is linearly traveling.

Furthermore, the device according to the present invention may further comprise means for recording the number of times of judgement of the state where the vehicle is traveling on a curved path in the traveling state judging means, means for judging whether or not the recorded number of times reaches a predetermined threshold, and means for initializing the initial correction factor when it is judged that the number of times reaches the threshold.

Since the initial data is found before the traveling state judging processing is performed, it may be actually found in a case where the vehicle is traveling on a road having an almost constant radius of curvature. In this case, the found initial data deviates from a true value which should be obtained when the vehicle is linearly traveling. If such initial data is used, therefore, it is difficult to discriminate the state where the vehicle is linearly traveling from the other state. There is a possibility that a precise initial correction factor cannot be eventually found.

The initial correction factor is calculated again from the beginning in a case where the number of times of judgement that the vehicle is traveling on a curved path (for example, a road having an almost constant radius of curvature) reaches the threshold. Although a time period elapsed until the factor is acquired is extended, a precise initial correction factor can be reliably obtained.

It is preferable that the device according to the present invention further comprises means for clearing the recorded number of times when it is judged that the vehicle is linearly traveling by the traveling state judging means.

A method for calculating a correction factor according to the present invention comprises a traveling state judging step for judging whether the vehicle is linearly traveling or the vehicle is traveling on a curved path on the basis of an output of rotational angular velocity detection means, and a factor calculating step for finding an initial correction factor for eliminating the effect of a difference in effective rolling radius between the tires depending on an initial difference on the rotational angular velocities of the tires on the basis of the output of the rotational angular velocity detection means when it is judged that the vehicle is linearly traveling.

In this case, it is preferable that the traveling state judging step comprises the steps of calculating the ratio of the rotational angular velocities of the right and left tires, and judging that the vehicle is linearly traveling if the difference or the ratio between the calculated ratio of the rotational angular velocities of the right and left tires and reference data is not more than a predetermined threshold, while judging that the vehicle is traveling on a curve- route if the difference or the ratio between the calculated ratio of the rotational angular velocities of the right and left tires and the reference data exceeds the threshold.

The foregoing and other objects, features, aspects and advantages of the present invention will become more apparent from the following detailed description of the present invention when taken in conjunction with the

accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a block diagram showing the construction of a tire pressure drop detecting device to which one embodiment of the present invention is applied;
Fig. 2 is a block diagram showing the electrical construction of the tire pressure drop detecting device;
Fig. 3 is a flow chart for explaining tire pressure drop detection processing;
Figs. 4 and 5 are flow charts for explaining STD (Straight Running Determination) processing;
Fig. 6 is a diagram showing the reciprocal of the turning radius of a vehicle in a case where the vehicle is turning a right angle corner and its time-differentiated value;
Fig. 7 is a diagram showing the reciprocal of the turning radius of a vehicle in a case where the vehicle is traveling on a constant-R road having a radius of curvature of 40 (m) and its time-differentiated value;
Fig. 8 is a diagram showing the reciprocal of the turning radius of a vehicle in a case where the vehicle is traveling on an exit road of an interchange having a radius of curvature of 50 (m) and its time-differentiated value; and
Fig. 9 is a diagram showing the reciprocal of the turning radius of a vehicle in a case where the vehicle is traveling on an exit road of an interchange having a radius of curvature of 200 (m) and its time-differentiated value.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Fig. 1 is a block diagram showing the construction of a tire pressure drop detecting device to which one embodiment of the present invention is applied. The tire pressure drop detecting device judges whether or not the air pressure of any one of four tires W_1, W_2, W_3, and W_4 provided in a four-wheel vehicle drops. The tires W_1 and W_2 respectively correspond to right and left front tires. The tires W_3 and W_4 respectively correspond to right and left rear tires.

A wheel speed sensor 1 is provided in relation to each of the tires W_1, W_2, W_3, and W_4. The outputs of the wheel speed sensors 1 are fed to a control unit 2.

A display 3 is connected to the control unit 2. The display 3 is for reporting the tire W_i (i = 1, 2, 3, 4) whose air pressure drops, and is constituted by a liquid crystal display, a plasma display, a CRT (Cathode-Ray Tube), or the like.

An initialising switch 4 is also connected to the control unit 2. The initializing switch 4 is operated by a user in calculating an initial correction factors K_j (j = 1, 2). The initial correction factors K_j are for eliminating the effect of a variation within a production torelance in effective rolling radius depending on an initial difference between the tires W_i from the rotational angular velocities F_i of the tires W_i.

Fig. 2 is a block diagram showing the electrical construction of the tire pressure drop detecting device. The control unit 2 is constituted by a microcomputer comprising an I/O interface 2a, a CPU 2b, a ROM 2c, a RAM 2d, and an EEPROM 2e.

The I/O interface 2a is required to deliver signals to external devices such as the wheel speed sensors 1 and the initializing switch 4. The CPU 2b is for performing various operation processing in accordance with a control operation program stored in the ROM 2c. The RAM 2d is one to which data or the like is temporarily written when the CPU 2b performs a control operation and from which the written data or the like is read out. A part of a storage area of the RAM 2d is utilized as counters 21 and 22 used in STD (Straight Running Determination) as described later for calculating initial correction factors K_j. The EEPROM 2e stores the initial correction factors K_j calculated in the STD processing.

Each of the wheel speed sensor 1 outputs a pulse signal corresponding to the speed of rotation of the tire W_i (hereinafter referred to as "wheel speed pulses"). In the CPU 2b, the rotational angular velocity F_i of each of the tires W_i is calculated for each predetermined sampling period ΔT (for example, ΔT = 1 (sec)) on the basis of the wheel speed pulses outputted from the wheel speed sensor 1.

Fig. 3 is a flow chart for explaining processing for detecting the drop in the air pressure of a tire in the tire pressure drop detecting device. The processing is performed for each sampling period ΔT in the control unit 2 by the CPU 2b operating in accordance with the predetermined program stored in the ROM 2c. In the following description, it is presupposed that an objective vehicle is an FF (front engine front drive) vehicle.

The CPU 2b first judges whether or not the initializing switch 4 is pressed (step S1). The initializing switch 4 is generally pressed by a user when the vehicle is first caused to travel, the tire W_i is filled with air pressure, or the tire W_i is replaced. In other words, the initializing switch 4 is generally pressed before the traveling is started or immediately after the traveling is started.

When the initializing switch 4 is pressed, the CPU 2b judges that an instruction to execute the STD processing is issued, and the execution of the STD processing is prepared (step S2). Specifically, a count value N of the counter 21 corresponding to the number of times of calculation of the initial correction factors K_j is cleared. Further, the initial correction factors K_1 and K_2 are respectively set to initial values k_0 (for example, k_0 = 1.0). Thereafter, the program proceeds to the step S3. On the other hand, when it is judged that the initializing switch 4 is not pressed, the program directly proceeds to the step S3.

In the tire pressure drop detection processing, the initial correction factors K_j are calculated a plurality of number of times for each sampling period ΔT in the STD

processing, and obtained values are averaged, to calculate a precise initial correction factors K_j. That is, the initial correction factors K_j are calculated by filtering processing for each sampling period ΔT. Consequently, the precision is increased every time the calculation is done.

The CPU 2b judges whether or not the count value N reaches its maximum value N_{max} (for example, $N_{max} = 500$) in the step S3. If the count value N is less than the maximum value N_{max}, it is considered that the precision of the initial correction factors K_j is still insufficient, so that the STD processing is executed (step S4). On the other hand, when it is judged that the count value N reaches the maximum value N_{max}, it is considered that a sufficiently precise initial correction factors K_j are obtained, so that normal tire pressure drop judgment processing (hereinafter referred to as "DWS processing") is executed (step S5).

The DWS processing will be briefly described. In the DWS processing, the rotational angular velocity F_i of each of the tires W_i is calculated on the basis of the wheel speed pulses outputted form the respective vehicle speed sensor 1. The calculated rotational angular velocities F_i are then subjected to initial correction processing. Specifically, the initial correction factors K_j calculated in the STD processing is used, so that processing as expressed by the following equations (3) to (6) is performed:

$$F1_1 = F_1 \quad (3)$$

$$F1_2 = K_1 \times F_2 \quad (4)$$

$$F1_3 = F_3 \quad (5)$$

$$F1_4 = K_2 \times F_4 \quad (6).$$

Consequently, rotational angular velocities $F1_i$ from which the effect of a difference in effective rolling radius depending on an initial difference between the tires W_i is eliminated are obtained. As apparent from the foregoing equations (3) to (6), the initial correction factor K_1 is a factor for eliminating the effect of the difference in effective rolling radius depending on the initial difference between the right and left front tires W_1 and W_2. Further, the initial correction factor K_2 is a factor for eliminating the effect of the difference in effective rolling radius depending on the initial difference between the right and left rear tires W_3 and W_4.

Thereafter, a judged value D for judging the drop in air pressure is calculated as expressed by the following equation (7) on the basis of the rotational angular velocities $F1_i$ thus obtained:

$$D = \frac{\frac{F1_1 + F1_4}{2} - \frac{F1_2 + F1_3}{2}}{\frac{F1_1 + F1_2 + F1_3 + F1_4}{4}} \times 100 \quad (7).$$

It is then judged whether or not the air pressure drops on the basis of the calculated judged value D. Specifically, it is judged whether or not the judged value D satisfies the following expression (8). In the following expression (8), $D_{TH1} = D_{TH2} = 0.1$, for example:

$$D > -D_{TH1} \text{ or } D > D_{TH2} \quad (8).$$

If the judged value D satisfies the foregoing expression (8), it is judged that the air pressure of any one of the tires W_i has dropped. On the other hand, if the judged value D does not satisfy the foregoing expression (8), it is judged that there is no tire W_i whose air pressure has dropped.

When it is judged that there is a tire W_i whose air pressure has dropped, data representing the judgment is fed to the display 3. In the display 3, the judgment that there is a tire W_i whose air pressure has dropped is displayed.

Figs. 4 and 5 are flow charts for explaining the STD processing. The CPU 2b first calculates the respective rotational angular velocities F_i of the tires W_i on the basis of the wheel speed pulses outputted from the wheel speed sensors 1 (step S41). Further, the reciprocal R of the turning radius of the vehicle which is a parameter for grasping the current traveling state of the vehicle is calculated on the basis of the calculated rotational angular velocities F_i (step S42). The reason why not the turning radius of the vehicle but the reciprocal thereof is taken as a parameter is that the value of the turning radius of the vehicle increases to infinity at the time of linear traveling, which is unsuitable for the processing in the CPU 2b, while the value of the reciprocal reaches zero at the time of linear traveling, which makes the processing in the CPU 2b easy. The reciprocal R of the turning radius of the vehicle is calculated in accordance with the following equation (9):

$$R = \frac{2}{Tw} \times \frac{F_3 - F_4}{F_3 + F_4} \quad (9).$$

The rotational angular velocities F_i may include errors depending on the speed of the vehicle (vehicle speed) V and the front/rear acceleration FRA_i of each of the tires W_i. Specifically, when the vehicle speed V is significantly low, the detection precision of the vehicle speed sensors 1 is significantly degraded, so that it is highly possible that the calculated rotational angular velocities F_i include errors. Further, when the front/rear acceleration FRA_i of each of the tires W_i is high, the effect of the slip of the tire W_i due to rapid acceleration/rapid deceleration of the vehicle, for example, is considered, so that it is highly possible that the calcu-

lated rotational angular velocities F_i include errors.

When it is thus highly possible that the rotational angular velocities F_i include errors, it is preferable that the rotational angular velocities F_i are rejected without being employed for detecting the drop in air pressure.

Therefore, the CPU 2b calculates the vehicle speed $\underline{V}$ and the front/rear acceleration FRA_i of each of the tires W_i on the basis of the rotational angular velocity F_i calculated in the step S41. It is judged whether or not the rotational angular velocities F_i calculated in the present sampling period ΔT should be rejected on the basis of the vehicle speed $\underline{V}$ and the front/rear acceleration FRA_i of each other tires W_i which are calculated (step S43).

More specifically, the vehicle speed V is calculated on the basis of the speed V_i of each of the tires W_i. The speed V_i of each of the tires W_i is calculated in accordance with the following equation (10), where $\underline{r}$ is a constant corresponding to the effective rolling radius at the time of linear traveling, and is stored in the ROM 2c:

$$V_i = r \times F_i \qquad (10).$$

The vehicle speed $\underline{V}$ is calculated by the following equation (11) on the basis of the calculated speed V_i of each of the tires W_i:

$$V = (V_1 + V_2 + V_3 + V_4) / 4 \qquad (11).$$

The front/rear acceleration FRA_i of each of the tires W_i is calculated by the following equation (12), letting BV_i be the speed of the tire W_i calculated in the preceding sampling period ΔT:

$$FRA_i = (V_i - BV_i) / (\Delta T \times 9.8) \qquad (12).$$

9.8 is inserted in the denominator in the foregoing equation (12) in order to convert the front/rear acceleration FRA_i of each of the tires W_i to a value in the unit of $\underline{G}$ (gravity acceleration).

It is then judged whether or not at least one of the following two conditions (1) and (2) is satisfied with respect to the vehicle speed $\underline{V}$ and the front/rear acceleration FRA_i of each of the tires W_i which are calculated:

(1) $V < V_{TH}$ (for example, V_{TH} = 15 (km/h))
(2) MAX $\{|FRA_i|\} > A_{TH}$
(for example, A_{TH} = 0.1 g : g = 9.8 (m/sec^2))

As a result, when either one of the foregoing conditions (1) and (2) is satisfied, the rotational angular velocities F_i are rejected, so that the program proceeds to the subsequent processing without doing calculation. On the other hand, when neither one of the foregoing conditions (1) and (2) is satisfied, the rotational angular velocities F_i are not rejected, so that processing for judging whether or not the vehicle is linearly traveling is performed.

More specifically, the CPU 2b pays attention to the fact that when the vehicle is linearly traveling, the turning radius of the vehicle is hardly changed on the time basis, so that a time-differentiated value $\underline{R'}$ of the reciprocal $\underline{R}$ of the turning radius of the vehicle is calculated as expressed by the following equation (13) (step S44). In the following equation (13), BR is the reciprocal of the turning radius of the vehicle which is calculated in the preceding sampling period ΔT, and is held in the RAM 2d:

$$R' = dR / dt = |R - BR| / \Delta T \qquad (13).$$

It is judged whether or not the calculated time-differentiated value $\underline{R'}$ falls in a predetermined allowable range R_{TH} (where R_{TH} represents a range of not less than R_{TH1} nor more than R_{TH2} : for example, R_{TH1} = -0.0005, and R_{TH2} = 0.0005) (step S45). If the time-differentiated value R' is outside the allowable range R_{TH}, it is judged that the vehicle is not linearly traveling. In this case, the rotational angular velocities F_i include errors caused by skidding of the tires W_i. If the rotational angular velocities F_i are used, therefore, a precise initial correction factors K_j cannot be calculated. In this case, therefore, the rotational angular velocities F_i are rejected, so that the program proceeds to the subsequent processing without doing calculation. On the other hand, if the time-differentiated value R' falls in the allowable range R_{TH}, it is judged that the vehicle is linearly traveling. In this case, the rotational angular velocities F_i faithfully represent a difference in effective rolling radius depending on an initial difference between the tires W_i. After the reciprocal $\underline{R}$ of the turning radius of the vehicle which is calculated in the step S42 is held as BR in the RAM 2d (step S46), therefore, processing for calculating the initial correction factors K_j using the rotational angular velocities F_i are performed.

When the vehicle turns a right angle corner, for example, it can be reliably judged in the step S45 that the vehicle is not linearly traveling. As an example, in a period $\underline{A}$ during which the vehicle turns a right angle corner, as shown in Fig. 6 the reciprocal $\underline{R}$ of the turning radius of the vehicle indicted by a solid line is increased, so that its time-differentiated value $\underline{R'}$ indicated by a broken line greatly exceeds the allowable range R_{TH}.

When the vehicle is traveling on a road curved at a constant radius of curvature (hereinafter referred to as a "constant-R road") such as an exit road of an interchange of a highway, however, it may be erroneously judged in the step S45 that the vehicle is linearly traveling. The reason for this is that the turning radius of the vehicle is approximately constant on the constant-R road, so that the time-differentiated value $\underline{R'}$ is approximately zero.

As an example, in a period $\underline{B}$ during which the vehicle is traveling on a constant-R road having a radius of curvature of 40 (m), the reciprocal $\underline{R}$ of the turning

radius of the vehicle is approximately constant, so that its time-differentiated value R' falls in the allowable range R_{TH}, which slightly varies, in many cases, as shown in Fig. 7. Therefore, it may be erroneously judged that the vehicle is linearly traveling.

When the vehicle is traveling on an exit road of an interchange having a radius of curvature of 50 (m), there are periods during which the reciprocal R of the turning radius of the vehicle is approximately zero, for example, periods C1 and C2, as shown in Fig. 8. Its time-differentiated value R' in these periods falls in the allowable range R_{TH}.

Furthermore, when the vehicle is traveling on an exit road of an interchange having a radius of curvature of 200 (m), a period during which the reciprocal R of the turning radius of the vehicle is in the vicinity of zero is long, so that a period during which its time-differentiated value R' falls in the allowable range R_{TH} is also long, as shown in Fig. 9.

When the vehicle is thus traveling on the exit road of the interchange, it may be erroneously judged that the vehicle is linearly traveling without depending on the radius of curvature.

On the other hand, when the vehicle is traveling on the constant-R road, the ratio of the rotational angular velocities of the right and left tires slightly changes with an elapse of time as described above. Specifically, the radius of curvature of an exit road of an interchange which is a typical example of the constant-R road is generally 60 (m) to 500 (m). In this case, a variation in the ratio of the rotational angular velocities of the right and left tires is 4 (%) to 1 (%) on average. In the STD processing, therefore, a threshold is set to a value which is less than the minimum value of a range in which the ratio of the rotational angular velocities of the right and left tires falls, to perform processing for discriminating between a state where the vehicle is traveling on the constant-R road and a state where it is linearly traveling (hereinafter referred to as supplemental discrimination processing).

Examples of reference data for the supplemental discrimination processing include the initial correction factor K_1 corresponding to the ratio of the rotational angular velocities of the right and left front tires W_1 and W_2 and the initial correction factors K_2 corresponding to the ratio of the rotational angular velocities of the right and left rear tires W_3 and W_4. On the other hand, each of the factors K_1 and K_2 is calculated by performing filtering processing for each sampling period ΔT, whereby the precision of the factors is increased every time the calculation is done. In the STD processing, therefore, the above-mentioned supplemental discrimination processing is performed after the precision of each of the initial correction factors K_1 and K_2 which is the reference data is sufficiently increased. Consequently, the supplemental discrimination processing can be performed with high precision from the beginning. In the present embodiment, the initial correction factors K_1 and K_2 in a period before the precision is sufficiently increased correspond to initial data.

The CPU 2b judges whether or not a count value N of a counter 21 is not less than a predetermined threshold N_{TH} (for example, N_{TH} = 11) prior to performing the above-mentioned supplemental discrimination processing (step S47). If the count value N is less than the threshold N_{TH}, it is judged that the precision of the initial correction factors K_1 and K_2 serving as the reference data is still insufficient, so that the initial correction factors K_j are directly calculated without performing the supplemental discrimination processing. Specifically, the count value N of the counter 21 is incremented by "1" (step S48), so that the number of times of calculation of the initial correction factors K_j are recorded. The count value N is then substituted in the number of data required for averaging (hereinafter referred to as "the number for averaging") (step S49), after which the initial correction factors K_j are calculated in accordance with the following equations (14) and (15) (step S50). In the following equations (14) and (15), BK_j represents the preceding initial correction factor K_j:

$$K_1 = \frac{NN - 1}{NN} \times BK_1 + \frac{1}{NN} \times \frac{F_2}{F_1} \quad (14)$$

$$K_2 = \frac{NN - 1}{NN} \times BK_2 + \frac{1}{NN} \times \frac{F_4}{F_3} \quad (15).$$

The calculated initial correction factors K_j are held as BK_j in the RAM 2d (step S51).

When the count value N reaches the threshold N_{TH} after repeating the foregoing processing, it is judged that the initial correction factors K_1 and K_2 having sufficient precision are obtained as the reference data, so that the supplemental discrimination processing is performed (step S52). More specifically, it is judged whether or not the difference between the ratio F_{avf} in the present sampling period of the rotational angular velocities F_1 and F_2 of the right and left front tires W_1 and W_2 and the initial correction factor K_1 is more than a predetermined threshold K_{TH} (for example, K_{TH} = 0.5 (%)), or whether or not the difference between the ratio F_{avf} in the present sampling period of the rotational angular velocities F_3 and F_4 of the right and left front tires W_3 and W_4 and the initial correction factor K_2 is more than the above-mentioned predetermined threshold K_{TH}. More specifically, it is judged whether or not conditions given by the following expression (16) are satisfied:

$$|F_{avf} - K_1| > K_{TH} \text{ or } |F_{avr} - K_2| > K_{TH} \quad (16).$$

When it is judged that neither one of the two conditions given by the foregoing expression (16) is satisfied, it is judged that the vehicle is not traveling on the con-

stant-R road but is linearly traveling. After the count value N is incremented by "1" (step S54), the initial correction factors K_j are calculated. In this case, a value obtained by subtracting (N_{TH} - 1) from the count value N is substituted, as expressed by the following equation (17), in the number for averaging NN in order to subtract the number of initial correction factors K_j whose precision is still insufficient which are calculated in a period before the supplemental discrimination processing is performed (step S55):

$$NN = N - (N_{TH} - 1) \quad (17).$$

The number for averaging NN is substituted in the foregoing equations (14) and (15), to calculate the initial correction factors K_j (step S50).

Processing for clearing the count value C of the counter 22 in the step S53 prior to the step of substituting a numerical value in the number for averaging NN, will be described later.

On the other hand, when it is judged in the foregoing step S52 that either one of the two conditions given by the foregoing expression (16) is satisfied, it is judged that the vehicle is traveling on the constant-R road, so that processing for judging whether or not the initial correction factors K_j should be calculated again from the beginning, skipping the calculation of the initial correction factors K_j in steps S56 to S58. That is, as described in "SUMMARY OF THE INVENTION", the reference data first used in the supplemental discrimination processing in the step S52 may deviate from the true basis which is a value in a case where the vehicle is linearly traveling. In this case, it is necessary to calculate the initial correction factors K_j again, to prevent the precision of the initial correction factors K_j from being decreased.

The above-mentioned judgment processing will be described in more detail. In the CPU 2b, the count value C of the counter 22 is incremented by "1" (step S56), and it is judged whether or not the count value C is not less than a predetermined threshold C_{TH} (for example, C_{TH} = 100) (step S57). If the count value C is less than the threshold C_{TH}, the program proceeds to the subsequent processing without doing calculation. On the other hand, if the count value C is not less than the threshold C_{TH}, it is judged that the initial correction factors K_j are unsuitable as reference data because it is calculated when the vehicle is traveling on the constant-R road, so that the count value N is cleared, and the initial correction factors K_j are set to an initial value k_0 (step S58).

It may, in some cases, be erroneously judged that the vehicle is traveling on the constant-R road by unexpected noise or the like, although the initial correction factors K_j have been actually calculated at the time of linear traveling. In such a case, if the count value C remains as it is, the initial correction factors K_j are calculated again, although they have been calculated with high precision. When it is judged that the vehicle is linearly traveling in the step S52, therefore, the count value C is cleared (step S53).

As described in the foregoing, according to the present embodiment, the supplemental discrimination processing is performed on the basis of the difference between the ratio of the rotational angular velocities of the right and left tires and the reference data. When the vehicle is traveling on the constant-R road, for example, therefore, it is not erroneously judged that the vehicle is linearly traveling. In other words, it can be reliably recognized that the vehicle is linearly traveling. Therefore, the initial correction factor can be found with high precision. Accordingly, the effect of the difference in effective rolling radius depending on the initial difference can be eliminated from the rotational angular velocities F_i. As a result, it can be reliably judged whether or not the air pressure of any one of the tires W_i has dropped.

Even if it is not examined whether or not a state where it is judged that the vehicle is linearly traveling is continuing for a predetermined time period, it can be reliably judged whether or not the vehicle is linearly traveling because the above-mentioned supplemental discrimination processing is performed. Accordingly, it can be reliably recognized that the vehicle is linearly traveling even in the case of short linear traveling. Even in an urban district in Japan where short straight roads and right angle corners connect with each other in may cases, therefore, a precise initial correction factors K_j can be rapidly obtained.

Although description has been made of the embodiment of the present invention, the present invention is not limited to the embodiment. For example, in the above-mentioned embodiment, the supplemental discrimination processing is not performed until the count value N reaches the threshold N_{TH} in order to improve the precision of the supplemental discrimination processing from the beginning. If the simplification of the processing, for example, is attached importance to, however, the supplemental discrimination processing may be performed from the beginning. In this case, as an initial value of the reference data, the average ratio of the rotational angular velocities of the right and left tires in a case where the vehicle is linearly traveling may be used.

Although in the present embodiment, the supplemental discrimination processing is performed on the basis of the difference between the ratio of the rotational angular velocities of the right and left tires and the reference data, it may be performed on the basis of the ratio of the rotational angular velocities of the right and left tires to the reference data. Specifically, when the vehicle is traveling on a constant-R road, the ratio of the rotational angular velocities of the right and left tires to the reference data generally falls in a predetermined range, similarly to the difference between the ratio of the rotational angular velocities of the right and left tires and the reference data.

Furthermore, although in the above-mentioned embodiment, it is judged whether or not the vehicle is linearly traveling on the basis of the time-differentiated value R' of the reciprocal R of the turning radius of the vehicle, it goes without saying that it may be judged whether or not the vehicle is linearly traveling on the basis of the time-differentiated value or values of the ratio of the rotational angular velocities of the right and left tires W_1 and W_2 and/or the ratio of the rotational angular velocities of the right and left rear tires W_3 and W_4, for example.

Although the present invention has been described and illustrated in detail, it is clearly understood that the same is by way of illustration and example only and is not to be taken by way of limitation.

Claims

1. A device for calculating a correction factor for correcting an output of rotational angular velocity detection means (1) for detecting rotational angular velocities of right and left tires mounted on a vehicle, comprising:

   traveling state judging means (S52) for judging whether the vehicle is linearly traveling or the vehicle is traveling on a curved path on the basis of the output of the rotational angular velocity detection means (1); and
   factor calculation means (S50) for finding an initial correction factor for eliminating an effect of a difference in effective rolling radius between the tires depending on an initial difference on the rotational angular velocities of the tires on the basis of the output of the rotational angular velocity detection means (1) when the traveling state judging means (S52) has judged that the vehicle is linearly traveling.

2. The device according to claim 1, wherein the traveling state judging means (S52) includes

   means for calculating a ratio of the rotational angular velocities of the right and left tires on the basis of the output of the rotational angular velocity detection means (1), and
   means for judging whether or not a difference or a ratio between the calculated ratio of the rotational angular velocities of the right and left tires and reference data which correspond to a ratio of the rotational angular velocities of the right and left tires previously calculated is less than a predetermined threshold, and judging that the vehicle is linearly traveling when it is judged that the difference or the ratio is not more than the threshold.

3. The device according to claim 2, wherein the factor calculation means (S50) subjects the ratio of the rotational angular velocities of the right and left tires which is obtained on the basis of the output of the rotational angular velocity detection means (1) and an initial correction factor previously found to averaging processing, to find an initial correction factor, the device further comprising

   means (S52) for taking the initial correction factor found by the factor calculation means (S50) as reference data to be used in the traveling state judging means.

4. The device according to any one of claims 1 to 3, further comprising

   means (S44) for calculating a time-differentiated value of a value corresponding to a turning radius of the vehicle on the basis of the output of the rotational angular velocity detection means (1), and
   means (S45) for allowing judging processing in the traveling state judging means (S52) to be performed on condition that the calculated time-differentiated value falls in a predetermined allowable range.

5. The device according to claim 4, further comprising

   means (S50) for subjecting a ratio of the rotational angular velocities of the right and left tires which is obtained on the basis of the output of the rotational angular velocity detection means (1) and initial data previously found to averaging processing, to find initial data,
   means (S48) for recording the number of times of calculation of the initial data,
   means (S47) for judging whether or not the recorded number of times of calculation reaches a predetermined threshold,
   means (S47) for inhibiting the judging processing in the traveling state judging means (S52) from being performed until it is judged that the number of times of calculation reaches the threshold, and
   means (S52) for setting the initial data as reference data to be first used in the traveling state judging means (S52).

6. The device according to claim 5, further comprising

   means (S45) for performing processing for finding the initial data on condition that the calculated time-differentiated value falls in the allowable range.

7. The device according to any one of claims 1 to 6,

further comprising

means (S56) for recording the number of times of judgement that the vehicle is traveling on a curved path in the traveling state judging means (S52),
means (S57) for judging whether or not the recorded number of times reaches a predetermined threshold, and
means (S58) for initializing the initial correction factor when it is judged that the number of times reaches the threshold.

8. The device according to claim 7, further comprising

means (S53) for clearing the recorded number of times when it is judged that the vehicle is linearly traveling by the traveling state judging means (S52).

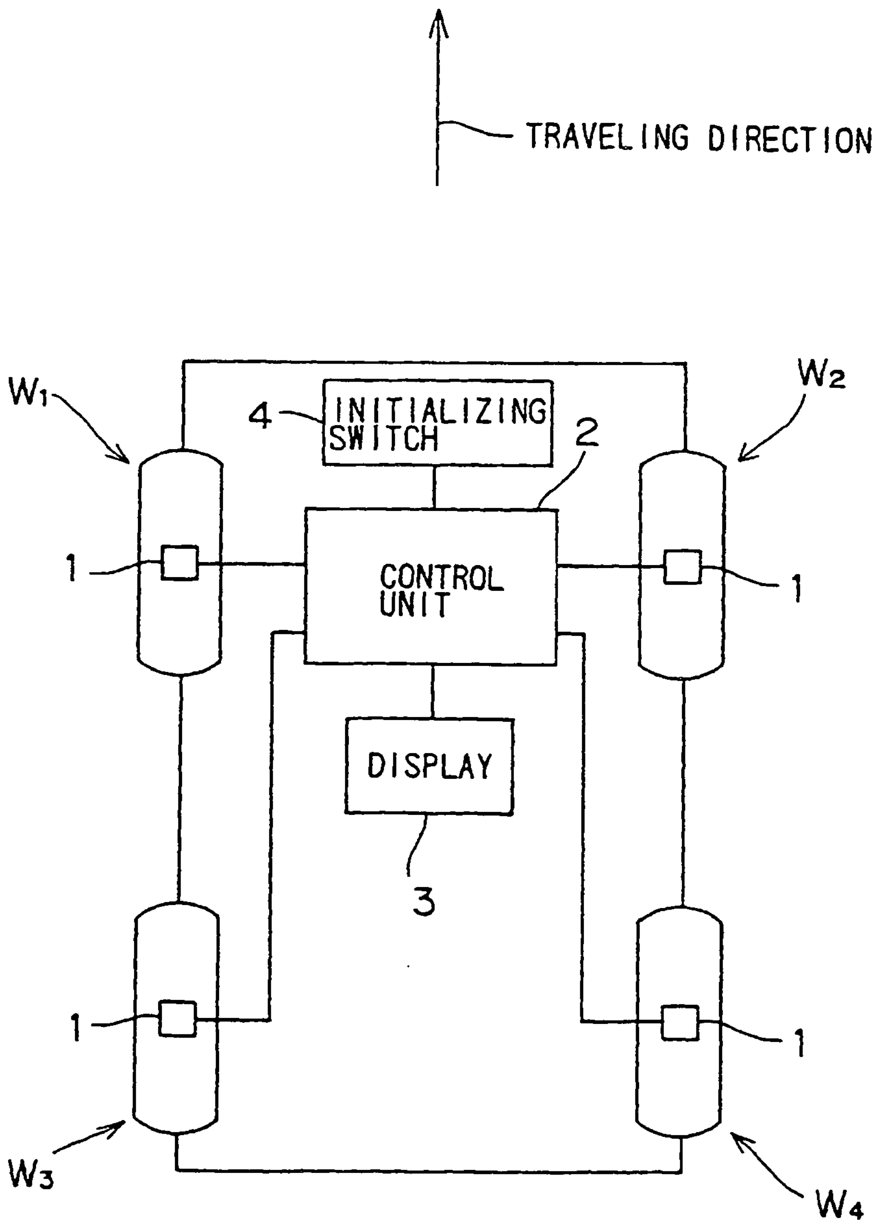
9. A method of calculating a correction factor for correcting an output of rotational angular velocity detection means (1) for detecting rotational angular velocities of right and left tires mounted on a vehicle, comprising:

a traveling state judging step of judging whether the vehicle is linearly traveling or the vehicle is traveling on a curved path on the basis of the output of the rotational angular velocity detection means (1); and
a factor calculating step of finding an initial correction factor for eliminating an effect of a difference in effective rolling radius between the tires depending on an initial difference on the rotational angular velocities of the tires on the basis of the output of the rotational angular velocity detection means (1) when it is judged that the vehicle is linearly traveling.

10. The method according to claim 9, wherein
the traveling state judging step includes the steps of

calculating a ratio of the rotational angular velocities of the right and left tires, and
judging that the vehicle is linearly traveling if a difference or a ratio between the calculated ratio of the rotational angular velocities of the right and left tires and reference data is not more than a predetermined threshold, while judging that the vehicle is traveling on a curved path if the difference or the ratio between the calculated ratio of the rotational angular velocities of the right and left tires and the reference data exceeds the threshold.

FIG. 1


TRAVELING DIRECTION
W1
W2
W3
W4
4
INITIALIZING SWITCH
2
CONTROL UNIT
1
1
1
1
DISPLAY
3

F I G. 2

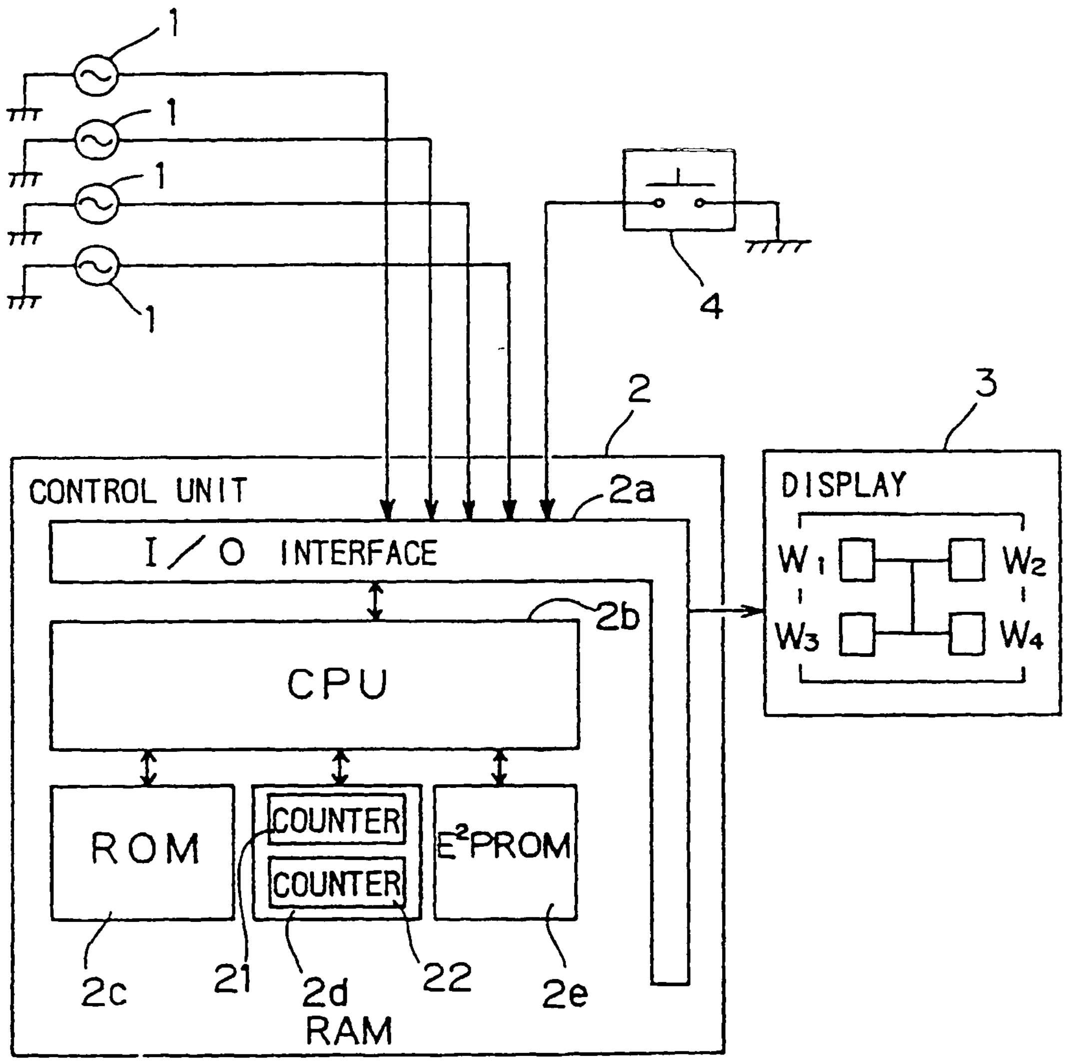
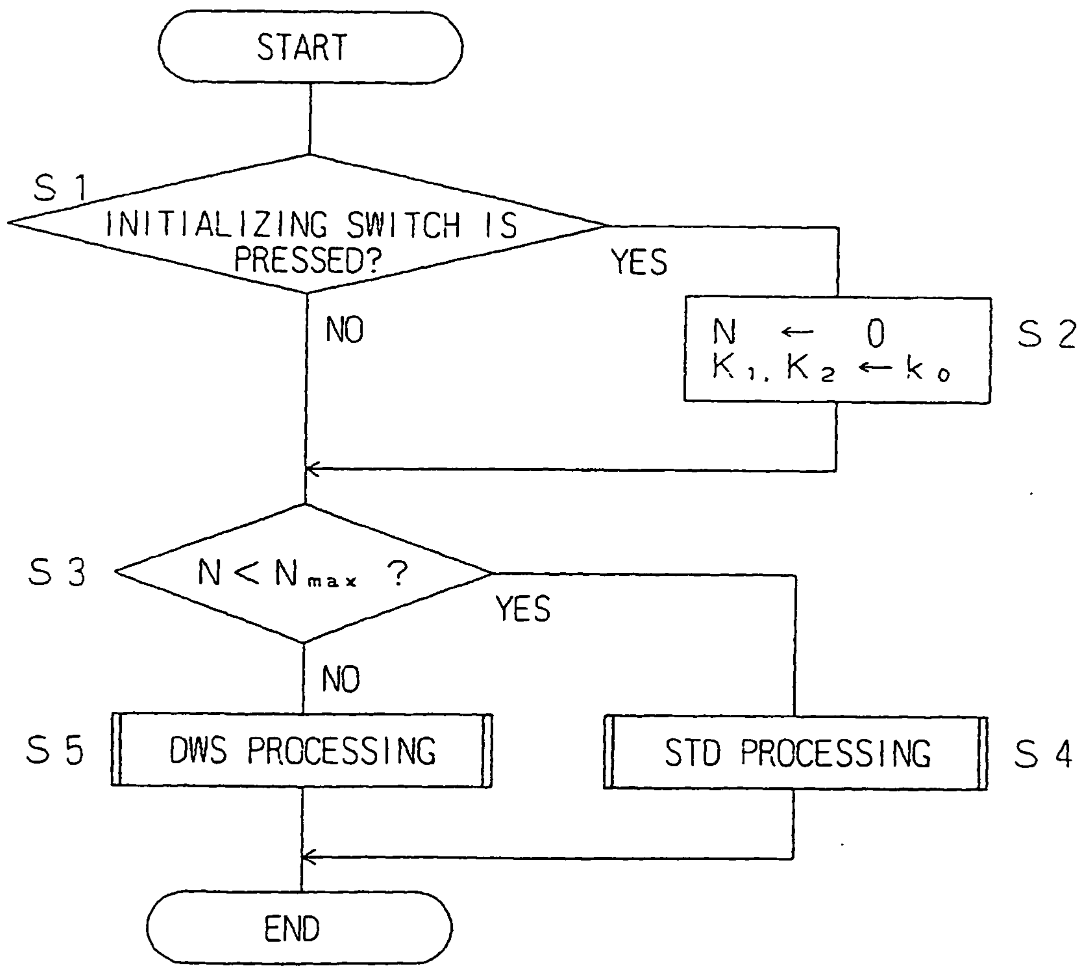

1
1
1
1
4
2
3
CONTROL UNIT
2a
I / O INTERFACE
2b
CPU
ROM
COUNTER
COUNTER
E²PROM
2c
21
2d
RAM
22
2e
DISPLAY
W1
W2
W3
W4

FIG. 3


START
S 1
INITIALIZING SWITCH IS PRESSED?
YES
NO
N ← 0
K1, K2 ← k0
S 2
S 3
N < Nmax ?
YES
NO
S 5
DWS PROCESSING
STD PROCESSING
S 4
END

F I G. 4

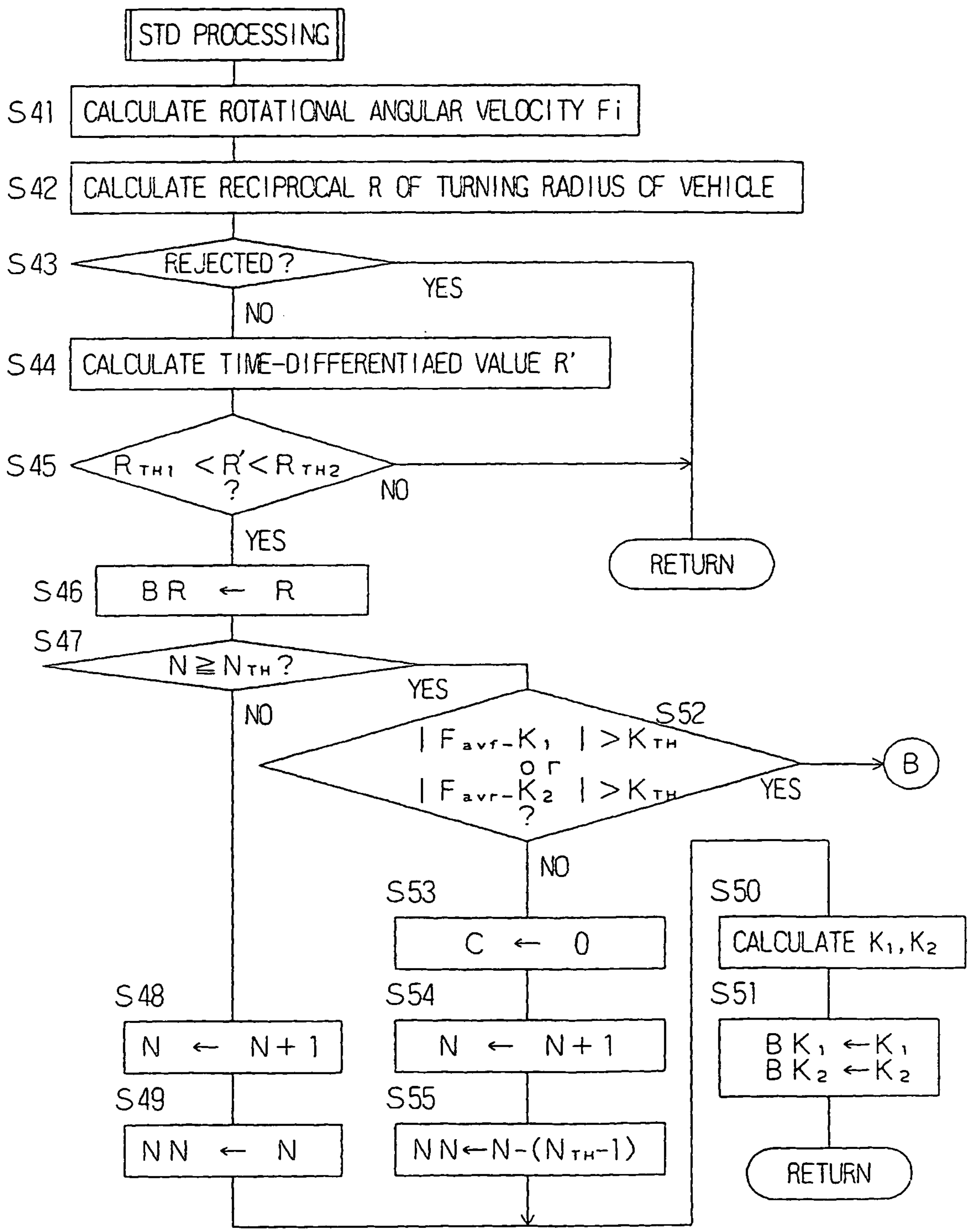

STD PROCESSING
S41
CALCULATE ROTATIONAL ANGULAR VELOCITY Fi
S42
CALCULATE RECIPROCAL R OF TURNING RADIUS OF VEHICLE
S43
REJECTED ?
YES
NO
S44
CALCULATE TIME-DIFFERENTIAED VALUE R'
S45
$R_{TH1} < R' < R_{TH2}$?
NO
YES
RETURN
S46
BR ← R
S47
$N \geqq N_{TH}$?
YES
NO
S52
$|F_{avr}-K_1| > K_{TH}$ or $|F_{avr}-K_2| > K_{TH}$?
B
YES
NO
S53
C ← 0
S50
CALCULATE K_1, K_2
S48
N ← N+1
S54
N ← N+1
S51
$BK_1 \leftarrow K_1$
$BK_2 \leftarrow K_2$
S49
NN ← N
S55
$NN \leftarrow N-(N_{TH}-1)$
RETURN

FIG. 5

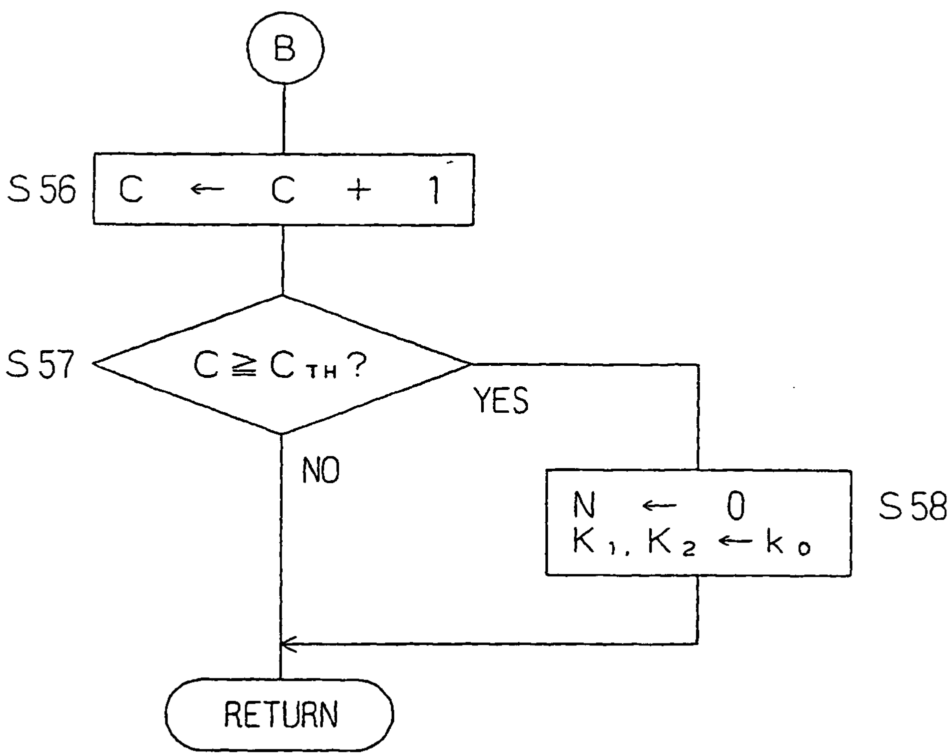


FIG. 6

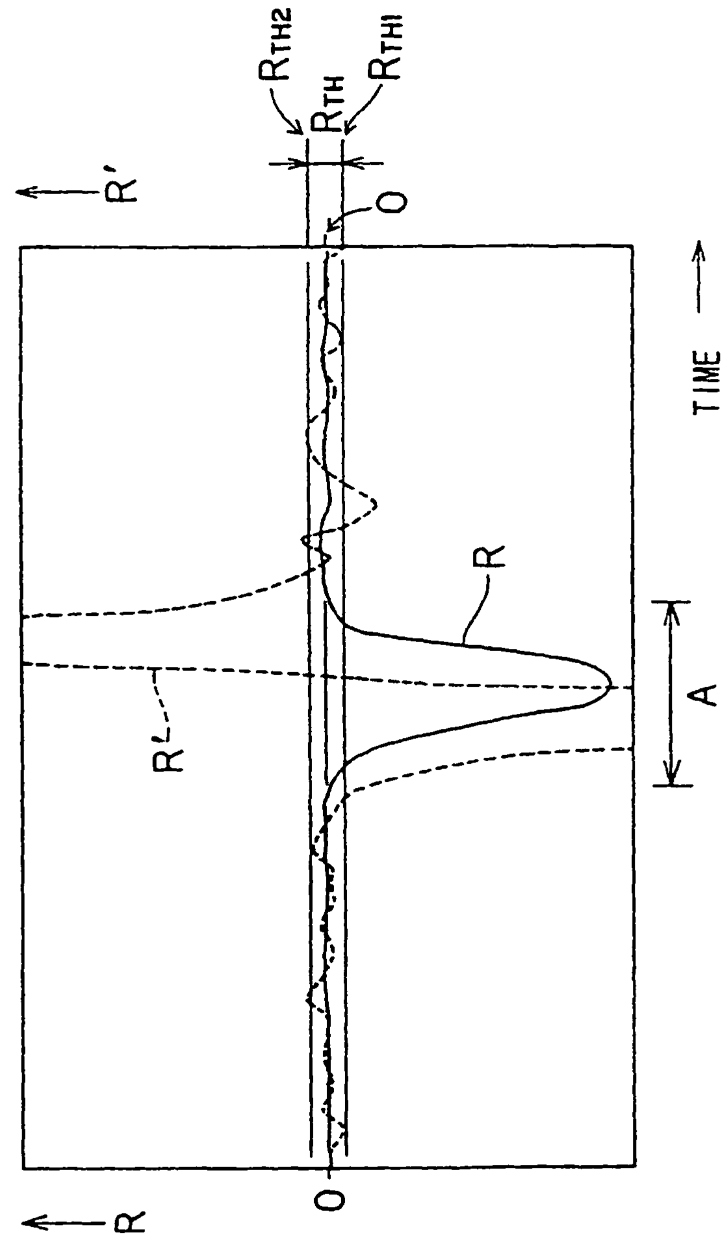


FIG. 7

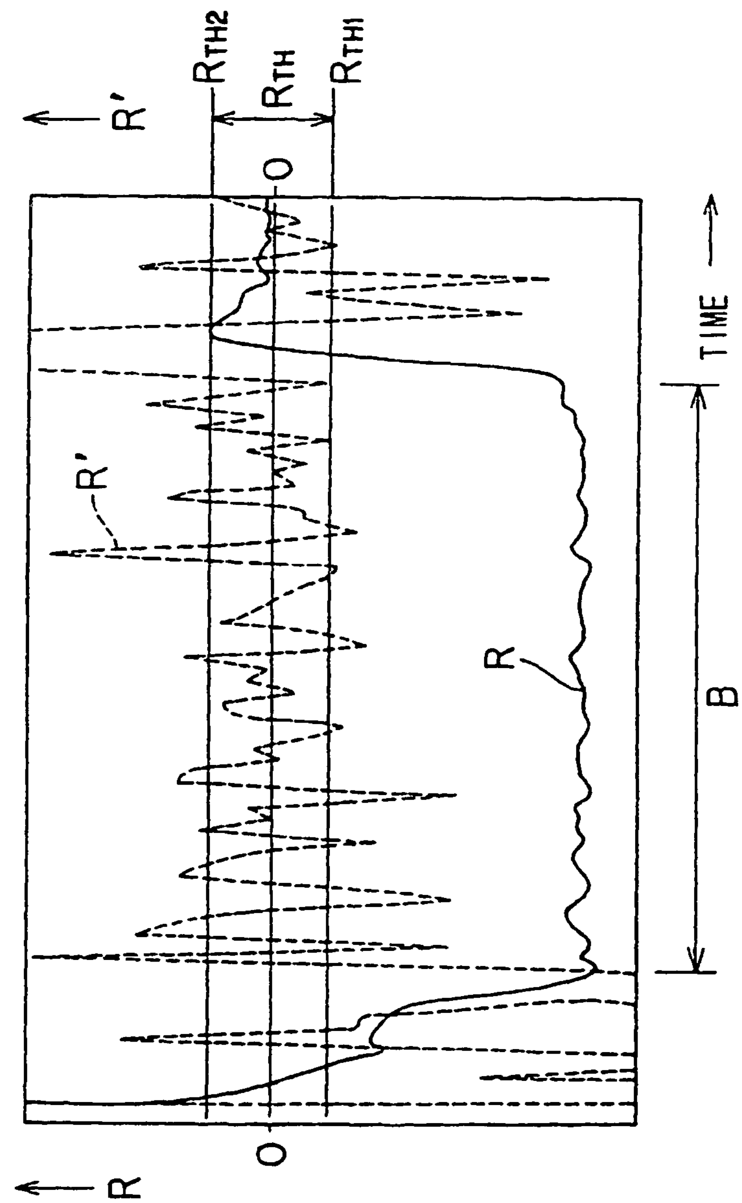


FIG. 8

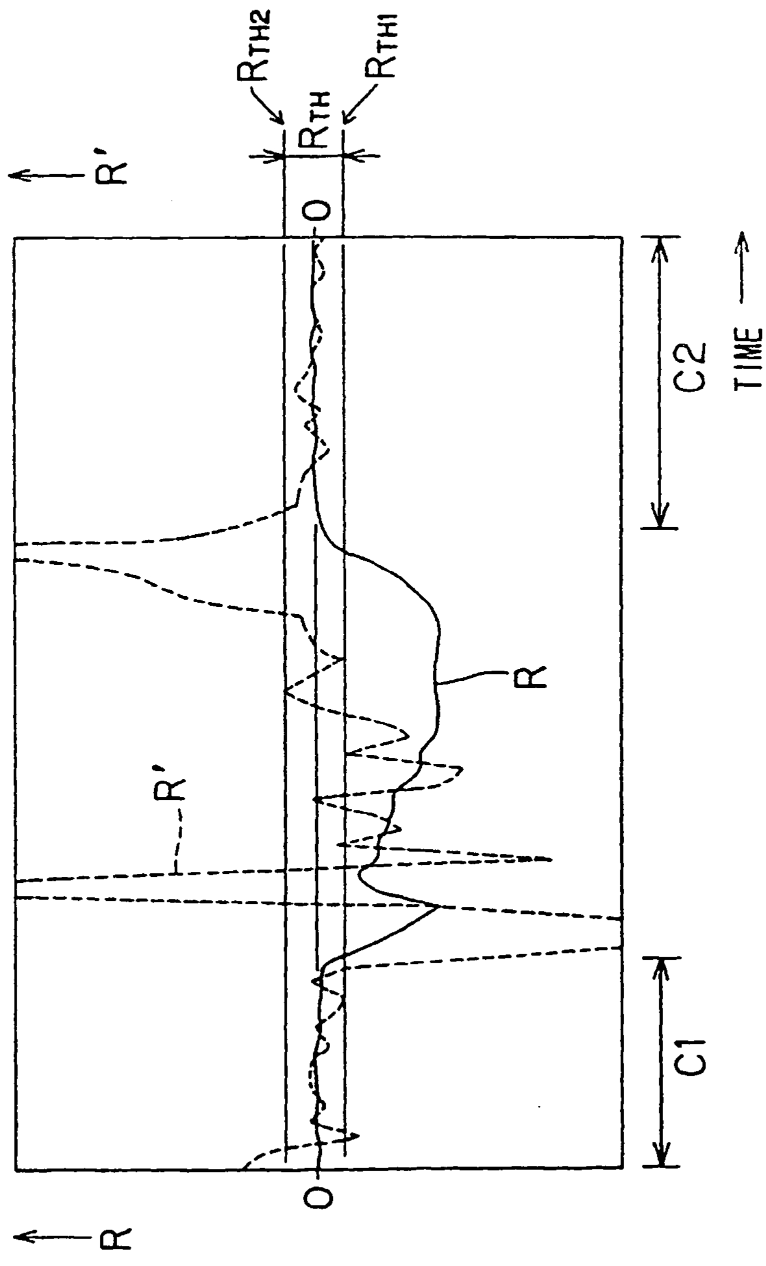
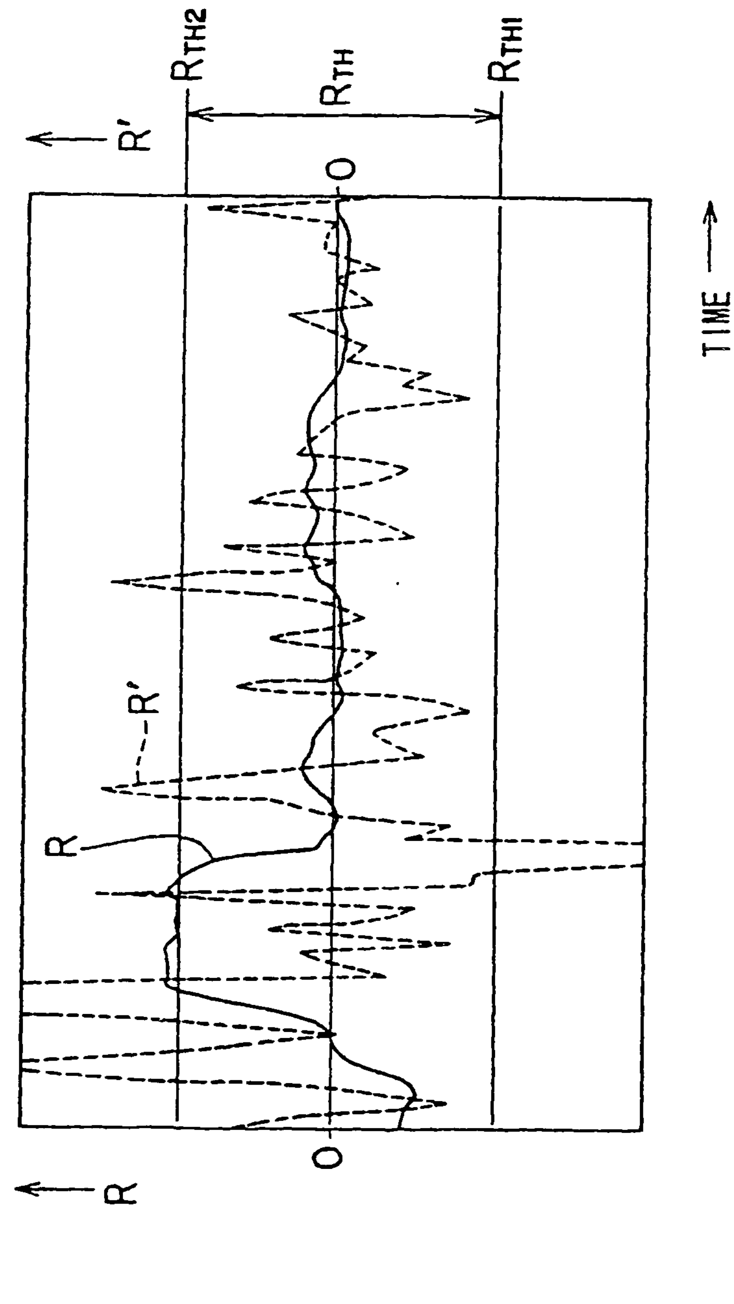


FIG. 9



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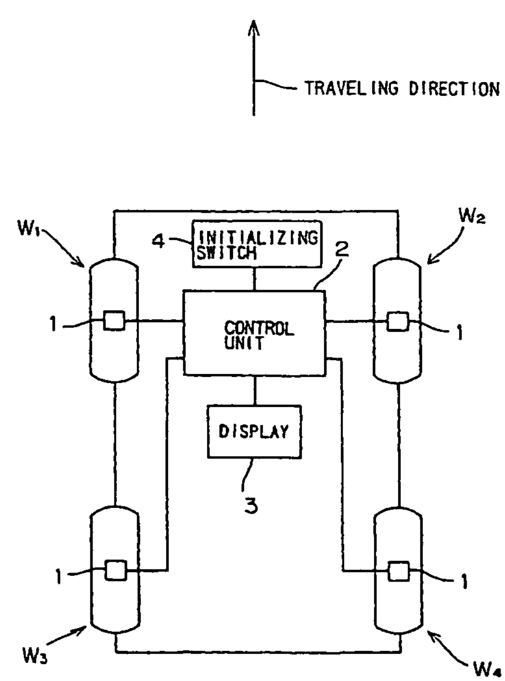
(54) **Device for calculating initial correction factor for correcting rotational angular velocity of tire**

(57) A device for calculating a correction factor for correcting an output of a rotational angular velocity detecting device for detecting the rotational angular velocities of right and left tires mounted on a vehicle. Discrimination between a state where the vehicle is linearly traveling and a state where the vehicle is traveling on a curved path is made on the basis of the output of the rotational angular velocity detecting device. Only when it is judged that the vehicle is linearly traveling, an initial correction factor for eliminating the effect of a difference in effective rolling radius between the tires depending on an initial difference on the rotational angular velocities of the tires is calculated.

F I G. 1



EP 0 861 743 A3

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 98 10 3304

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
X	US 5 583 483 A (BAUMANN MATTHIAS) 10 December 1996 (1996-12-10) * column 2, line 39 - column 3, line 38 * * column 4, line 23 - column 5, line 11 * * column 6, line 1 - column 6, line 54 * * column 7, line 43 - column 7, line 67 *	1-10	B60C23/06
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X	WO 89 04783 A (BOSCH GMBH ROBERT) 1 June 1989 (1989-06-01) * page 1, paragraph 3 - page 2, paragraph 1 * * page 3, paragraph 1 - page 5, paragraph 3 * * page 6, paragraph 3 * * page 7, paragraph 3 * * claims 12,17,19,25 *	1-3,5,9, 10	
			TECHNICAL FIELDS SEARCHED (Int.Cl.6)
			B60C B60T

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	18 July 2000	Deraymaeker, D

CATEGORY OF CITED DOCUMENTS

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18-07-2000

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